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Responsible Office: Science Mission Directorate

Chapter 5 Detailed Planetary Protection Requirements

5.1 Numerical Implementation Limits for Forward Contamination Calculations not Otherwise Specified

5.1.1 To the degree that numerical limits are required to support the overall policy objectives of this document, and except where numerical requirements are otherwise specified, the limit to be used is that the probability that a planetary body will be contaminated during the period of biological exploration shall be no more than 1x10-3. No specific format for probability of contamination calculations is specified.

5.1.2 The period of biological exploration shall extend at least 50 years after a PP Category III or IV mission arrives at its protected target and no longer than the time point after which no organisms remain viable on the spacecraft.

5.1.3 For all launch vehicle elements leaving Earth's orbit, the probability of impacting Mars shall be less than 1x10-4 for a period of 50 years. The probability of impact assessment should be provided in the Planetary Protection Plan.

5.1.4 For all spacecraft crossing Mars orbit en route to other targets, the probability of impacting Mars shall be less than 1x10-2 for a period of 50 years. The probability of impact assessment should be provided in the Planetary Protection Plan.

5.1.5 In the context of missions to icy satellites, "contamination" is defined as the introduction of a single viable terrestrial microorganism into a liquid-water environment.

5.2 PP Category-Specific Listing of Target Body/Mission Types (advisory only)

5.2.1 PP Category I (Flyby, Orbiter, Lander): Undifferentiated, metamorphosed asteroids; Io; others TBD

5.2.2 PP Category II (Flyby, Orbiter, Lander): Venus; Moon (with organic inventory); Comets; Asteroids (other than those covered in 5.2.1); Jupiter; Jovian Satellites except Io, Ganymede* (see 5.2.2.1 for explanation of the asterisk), and Europa; Saturn; Saturnian Satellites other than Titan* and Enceladus; Uranus; Uranian Satellites; Neptune; Neptunian Satellites other than Triton*; Pluto*/Charon*; Kuiper-Belt Objects

5.2.2.1 The mission-specific assignment of objects designated with an asterisk (*) to Category II shall be supported by an analysis of the "remote" potential for contamination of the liquid-water environments that may exist beneath their surfaces (a probability of < 1x10-4 of introducing a single viable terrestrial microorganism), addressing both the existence of such environments and the prospects of accessing them.

5.2.3 PP Category III (Flyby, Orbiter): Mars; Europa; Enceladus; others TBD.

5.2.4 PP Category IV (Lander): Mars; Europa; Enceladus; others TBD

5.2.5 PP Category V (Any Earth-return): "Restricted Earth return": Mars; Europa; Enceladus; others TBD; "Unrestricted Earth return": Venus, Moon; others TBD.

5.3 PP Category-specific Requirements for Mars

Note: All bioburden constraints are defined with respect to the number of aerobic microorganisms that survive a heat shock of 353 Kelvin (80C) for 15 minutes and are cultured on Trypticase Soy Agar at 305 Kelvin (32C) for 72 hours (hereinafter "spores").

5.3.1 PP Category III and IV missions to Mars shall comply with all applicable requirements, including appropriate margin.

5.3.1.1 A probability of impact assessment shall be provided for all launch vehicle elements leaving Earth's orbit, covering the first fifty years after launch.

5.3.1.2 Cruise stages, flyby, and orbiter spacecraft shall avoid Mars impact at a probability no less than 0.99 for 20 years after launch and a probability no less than 0.95 for the period 20-50 years after launch.

5.3.1.3 Mars orbiters shall include the probability of impact on approach in their calculations, unless numerical bioburden requirements are met at launch.

5.3.1.4 Spacecraft that do not meet impact avoidance constraints shall limit their total (surface, mated, and encapsulated) bioburden level to 5 x 105 spores.

5.3.2 PP Category IV for Mars is subdivided into IVa, IVb, and IVc. Missions shall comply with requirements appropriate to the subcategory they have been assigned. Requirements for missions carrying life detection instruments that access special regions will include a combination of those listed under IVb and IVc, as determined on a mission-by-mission basis.

5.3.2.1 PP Category IVa. Lander systems not carrying instruments for the investigations of extant Martian life shall:

a. Be restricted to a surface biological burden level of 3 x 105 spores in total and an average of 300 spores per square meter of exposed external and internal spacecraft surfaces.

b. Provide an assessment of Entry, Descent, and Landing (EDL) expected performance against environmental and other design cases, identifying included and excluded factors, and, to the extent available, quantitative assessments of confidence levels.

5.3.2.2 PP Category IVb. Lander systems designed to investigate extant Martian life shall comply with all of the requirements of PP Category IVa and also with one of the following requirements:

EITHER

a. The entire landed system is restricted to a surface biological burden level of 30 spores (see 5.3.2.4) or to levels of biological burden reduction driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent, and protected from recontamination.

OR

b. The subsystems which are involved in the acquisition, delivery, and analysis of samples used for life detection are sterilized to these levels. Methods for preventing recontamination of the sterilized subsystems and preventing contamination of the material to be analyzed is provided.

5.3.2.3 PP Category IVc. Missions investigating Martian special regions (see section 5.3.2.4), even if they do not include life detection experiments, shall comply with all of the requirements of PP Category IVa and also the following:

a. For missions landing within a special region, the entire landed system shall be restricted to a surface biological burden level of 30 spores (see 5.3.2.4).

b. For missions accessing a special region though horizontal or vertical mobility, one of the following requirements shall be imposed:

EITHER

(1) The entire landed system is restricted to a surface biological burden level of 30 spores (see 5.3.2.4);

OR

(2) The subsystems which directly contact the special region are sterilized to these levels, and a method of preventing their recontamination prior to accessing the special region is provided.

c. If the probability of a non-nominal landing in a special region (including EDL and spacecraft-induced special regions) is greater than 0.01, then the entire landed system shall be sterilized to the following levels: a surface biological burden level of 30 spores (see 5.3.2.4) and a total (surface, mated, and encapsulated) bioburden level of

1.5x104 spores (see 5.3.2.4).

5.3.2.4 The 30 spore figure takes into account the occurrence of hardy organisms with respect to the sterilization modality. This specification assumes attainment of PP Category IVa surface cleanliness, followed by at least a four order-of-magnitude reduction in viable organisms. Verification of bioburden level is based on presterilization bioburden assessment and knowledge of reduction factor for the sterilization modality.

5.3.2.5 A Special Region shall be defined as a region within which terrestrial organisms are likely to replicate. Any region which is interpreted to have a high potential for the existence of extant Martian life forms is also defined as a Special Region.

a. Given current understanding of terrestrial organisms, Special Regions are defined as areas or volumes within which sufficient water activity AND sufficiently warm temperatures to permit replication of Earth organisms may exist. The physical parameters delineating applicable water activity and temperature thresholds are given below:

(1) Lower limit for water activity: 0.5 aw; Upper limit: 1.0 aw

(2) Lower limit for temperature: -25C; No Upper limit defined

(3) Timescale over which limits apply: 500 years

b. Observed features for which there is a significant (but still unknown) probability of association with liquid water and which should be classified as Special Regions:

(1) Gullies and bright streaks associated with gullies

(2) Pasted-on terrains

(3) Subsurface below 5 meters

(4) Others, to be determined, including dark streaks, possible geothermal sites, fresh craters with hydrothermal activity, modern outflow channels, or sites of recent seismic activity.

c. Spacecraft-induced Special Regions are to be evaluated, consistent with these limits and features, on a case-by-case basis.

d. In the absence of specific information, no Special Regions are currently identified on the basis of possible Martian life forms. If and when information becomes available on this subject, Special Regions shall be further defined on that basis.

5.3.3 PP Category V. The Earth return portion of a Mars Sample Return mission is classified as "Restricted Earth return," with all outbound portions required to meet associated requirements. Guidelines for sample return missions are as follows:

5.3.3.1 Samples returned from Mars by spacecraft shall be contained and treated as though potentially hazardous until demonstrated otherwise.

5.3.3.2 Unless specifically exempted, the outbound leg of the mission shall meet PP Category IVb requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned.

a. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later Mars missions.

5.3.3.3 Unless the sample to be returned is subjected to an accepted, approved, sterilization process, the sample container must be sealed after sample acquisition, and a redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required.

5.3.3.4 For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

5.3.3.5 The mission and the spacecraft design shall provide a method to "break the chain of contact" with Mars. No uncontained hardware that contacted Mars, directly or indirectly, may be returned to Earth unless sterilized. Isolation of such hardware from the Mars environment must be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.

5.3.3.6 Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth reentry.

5.3.3.7 For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

5.3.3.8 Because of the lengthy time needed for the complex development of a sample-receiving facility (SRF) and its associated biohazard-test protocol, instrumentation, and operations, planning for an SRF shall be included in the earliest phases of the Mars sample return mission.

5.3.3.9 A sample-receiving facility shall be completed and fully operational prior to the return of samples to Earth, on a timescale that allows ample time for integrated testing of the facility, the instrumentation, and the NASA life detection and biohazard test protocol, well in advance of receiving returned Martian materials.

5.3.3.10 A sample-receiving facility shall employ appropriately certified personnel and instrumentation to validate and perform the battery of tests described in the NASA life detection and biohazard test protocol that will be used to determine whether and when unsterilized materials returned from Mars may be approved for controlled distribution or full release from containment.

5.3.3.11 An independent science and technical advisory committee shall be constituted with oversight responsibilities for materials returned by a Mars sample return mission.

5.4 PP Category II*/III/IV Requirements for Icy Satellites

5.4.1 PP Category II*, III and IV. (For an explanation of the II* designation, see section 5.2.2.1.) Requirements for flybys, orbiters, and landers to icy satellites, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of an ocean or other liquid water body to less than 1 x 10-4 per mission. The calculation of this probability shall include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

A. Bioburden at launch

B. Cruise survival for contaminating organisms

C. Organism survival in the radiation environment adjacent to the target

D. Probability of encountering/landing on the target, including spacecraft reliability

E. Probability of surviving landing/impact on the target

F. Mechanisms and timescales of transport to the subsurface

G. Organism survival and proliferation before, during, and after subsurface transfer

5.4.1.1 Preliminary calculations of the probability of contamination suggest that bioburden reduction will likely be necessary for PP Category III orbiters, as well as for PP Category IV landers, requiring the use of cleanroom technology and the cleanliness of all parts before assembly and the monitoring of spacecraft assembly facilities to understand the bioload and its microbial diversity, including specific problematic species.

5.4.2 PP Category V for Europa and Enceladus. The Earth return mission is classified "Restricted Earth return."

5.4.2.1 Unless specifically exempted, the outbound leg of the mission shall meet the contamination control requirements given above. This provision should avoid "false positive" indications in a life-detection and hazard-determination protocol or in the search for life in the sample after it is returned.

a. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later missions.

5.4.2.2 Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container must be sealed after sample acquisition, and a redundant, fail-safe containment with a method for verification of its operation before Earth-return shall be required.

5.4.2.3 For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

5.4.2.4 The mission and the spacecraft design shall provide a method to "break the chain of contact" with the target.

5.4.2.5 No uncontained hardware that contacted the target, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the target environment must be provided during sample container loading into the containment system, launch from the target, and any in-flight transfer operations required by the mission.

5.4.2.6 Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving the target for return to Earth; and 3) prior to commitment to Earth reentry.

5.4.2.7 For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

5.5 Requirements for Small Solar System Bodies

5.5.1 PP Category I, II, III, or IV. The small bodies of the solar system, not elsewhere discussed in this policy, represent a very large class of objects. Imposing forward contamination controls on these missions is not warranted except on a case-by-case basis, so most such missions are likely to be assigned to PP Categories I or II. Further elaboration of this requirement is anticipated.

5.5.2 PP Category V. Determination as to whether a mission is classified "Restricted Earth return" or "Unrestricted Earth return" shall reflect the best multidisciplinary scientific advice and review, using the framework presented in the 1998 report of the US National Research Council's Space Studies Board entitled, Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making (SSB 1998).

5.5.2.1 Specifically, such a determination shall consider six questions for each body intended to be sampled. Containment procedures are necessary ("Restricted Earth return") if an answer of "yes" or "uncertain" is returned to each of the six questions, below. A "no" answer to any one of these questions would indicate that containment of returned samples from the target body is not necessary for planetary protection purposes ("Unrestricted Earth return"):

Does scientific evidence indicate that:

1. There was ever liquid water in or on the target body?

2. Metabolically useful energy sources are or were ever present?

3. Sufficient organic matter (or CO_2 or carbonates and an appropriate source of reducing equivalents to support life) was ever in or on the target body?

4. Subsequent to the disappearance of liquid water, the target body has remained below the temperature of presumptive biological sterilization (e.g.,

5. The target body has not been exposed to sufficient radiation for presumptive biological sterilization (e.g., by analogy to the tolerances of terrestrial organisms)?

6. There is no natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

5.5.3 For missions determined to be PP Category V, "Restricted Earth return," the following requirements shall be met:

5.5.3.1 Unless specifically exempted, the outbound leg of the mission shall meet contamination control requirements to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in any search for life in the sample after it is returned.

a. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later missions to that body.

5.5.3.2 Unless the sample to be returned is subjected to an accepted and approved sterilization process, the sample container shall be sealed after sample acquisition, and a redundant, fail-safe containment with a method for verification of its operation before Earth-return be required.

5.5.3.3 For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility.

5.5.3.4 The mission and the spacecraft design shall provide a method to "break the chain of contact" with the small body. No uncontained hardware that contacted the body, directly or indirectly, may be returned to Earth. Isolation of such hardware from the body's environment must be provided during sample container loading into the containment system, launch from the body, and any in-flight transfer operations required by the mission.

5.5.3.5 Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving the body or its environment for return to Earth; and 3) prior to commitment to Earth reentry.

5.5.3.6 For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

5.6 Additional Implementation Guidelines for PP Category V Missions

5.6.1 If, during the course of a PP Category V mission there is an increase in the level of concern, due to a change in the circumstances that led to its classification or a mission failure, then the sample to be returned shall be

abandoned.

5.6.1.1 If the sample is already collected, the spacecraft carrying it shall not be allowed to return to the Earth or the Moon.

5.6.2 Examples of such changes include:

a. New data or scientific opinion arise that would lead to the reclassification of a mission classified as "Unrestricted Earth return" to "Restricted Earth return," and safe return of the sample cannot be assured.

b. The sample containment system of a mission classified as "Restricted Earth return" is thought to be compromised, and sample sterilization is impossible.

c. Others TBD.

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